Medial Elbow Exposure for Coronoid Fractures: FCU-Split Versus Over-the-Top

Jeannie Huh, MD, Chad A. Krueger, MD,* Michael J. Medvecky, MD,† and Joseph R. Hsu, MD,‡ Skeletal Trauma Research Consortium (STReC)*

Objective: The optimal exposure interval for anteromedial coronoid fractures is unknown. The purpose of this study was to quantitatively compare the osseous and ligamentous exposure of the medial elbow using the flexor carpi ulnaris (FCU)-Splitting and Hotchkiss Over-the-Top approaches.

Methods: Forty surgical approaches were performed on 20 fresh-frozen cadaveric elbows using a randomized crossover design. Access to key anatomic landmarks [anteromedial facet, coronoid tip, sublime tubercle/anterior bundle of the medial collateral ligament (MCL), posterior bundle of the MCL, and radial head] was assessed. A calibrated digital image was taken from the surgeon's perspective of each approach, and these images were analyzed using a software program, ImageJ (NIH), to calculate the surface area of osseous structures exposed.

Results: The average surface area exposed was 3 times greater with the FCU-Splitting approach (13.3 cm^2) compared with the Hotchkiss Over-the-Top approach (4.4 cm^2) ($P < 0.0001$). All key anatomic landmarks were directly visualized with the FCU-Splitting approach in each specimen. Visualization of the sublime tubercle/anterior bundle of the MCL and posterior bundle of the MCL was unobtainable with the Hotchkiss approach in 17 (85%) and 20 (100%) specimens, respectively. There were no statistically significant correlations between exposure and sequence of dissection, specimen age, gender, or laterality.

Conclusions: The FCU-Splitting approach provides more extensive exposure of the anteromedial coronoid and proximal ulna and the medial ligamentous structures than the Hotchkiss Over-the-Top approach.

Key Words: medial elbow, surgical exposure, coronoid anteromedial facet fracture, Hotchkiss Over-the-Top, FCU-Splitting

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From the *Department of Orthopaedic Surgery and Rehabilitation, Brooke Army Medical Center, Fort Sam Houston, TX; †Department of Orthopaedics & Rehabilitation, Yale University School of Medicine, New Haven, CT; and ‡United States Army Institute of Surgical Research (USAISR), Fort Sam Houston, TX.

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Reprints: Chad A. Krueger, MD, Brooke Army Medical Center, Building 3600, 3851 Roger Brooke Drive, Fort Sam Houston, TX 78234-6200 (e-mail: chad.krueger@amedd.army.mil).

INTRODUCTION

Recent biomechanical and clinical studies have brought attention to the role of the coronoid process as an important stabilizer of the elbow.[1–4] In addition to serving as an anterior buttress to posterior translation of the ulna, the coronoid provides attachment for the anterior bundle of the medial collateral ligament (MCL) at the sublime tubercle, providing significant resistance to valgus stress of the elbow. Thus, coronoid integrity is essential in elbow stability and merits surgical fixation when fractured.

Fractures of the anteromedial facet of the coronoid are a distinct injury pattern associated with varus posteromedial rotatory instability. When left untreated, these fractures result in incongruent articulation of the ulnohumeral joint under gravitational varus stress and a predisposition for rapid post-traumatic arthritis.[3,5] Although surgical approach depends on presence of concomitant ligamentous and bony injury,[6,7] medial elbow exposure is usually required for reduction and fixation of these fractures.[8] The majority of anteromedial facet fractures are small shearing type fragments that are well suited to buttress plating. Adequate plate position is important and is largely dependent on available exposure of the fracture site.

From the medial elbow, the coronoid can be exposed in 1 of 3 ways.[9–12] Taylor and Scham[11] described elevation of the entire flexor-pronator mass off the medial ulna, but this requires extensive dissection and is often more than necessary for fractures that do not extend into the base of the coronoid. A more anterior exposure is gained using the Hotchkiss Over-the-Top technique, which was originally described for elbow contracture release,[12] but is frequently used for addressing small coronoid fractures that remain anterior to the sublime tubercle.[9,10] This approach involves detaching a portion of the flexor-pronator origin off the medial epicondyle. Alternatively, for fractures that involve the sublime tubercle, the flexor carpi ulnaris (FCU)-Splitting approach has been suggested, which uses the natural split between the 2 heads of the FCU.[3,6,10] It is unclear what quantitative differences in exposure exist between these latter 2 approaches. However, our clinical experience has led us to believe that the FCU-Splitting approach appears to be less traumatic and technically easier while allowing adequate exposure of all potential fracture subtypes of the anteromedial coronoid.

The purpose of this study was to quantitatively compare the osseous and ligamentous exposure of the medial elbow, including key anatomic landmarks, using the FCU-Splitting and Hotchkiss Over-the-Top techniques. To our knowledge, such quantification and description comparing these 2 surgical

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approaches to the medial elbow has not been previously described in the literature.

MATERIALS AND METHODS

Study Design

Twenty thawed, fresh-frozen cadaveric hemicorporectomy specimens were used. None of these specimens had evidence of previous surgery, trauma, or arthrofibrosis to the elbow. Using a randomized crossover design for surgical sequence, the cadaveric limbs were randomized to undergo either the FCU-splitting or the Hotchkiss Over-the-Top surgical exposure first. Upon completion of the first approach, the limbs were then crossed over so that each elbow underwent the latter approach, resulting in a total of 40 cadaveric dissections. All approaches were performed by a single board-certified orthopedic trauma surgeon (J.R.H.).

Surgical Procedure

For each limb, a single 20-cm universal posterior skin incision just medial of midline from the olecranon was used.[13] This was followed by development of a medial skin flap. This sequence was used as it was thought to best simulate what would be done during the actual surgical treatment of a coronoid injury. The 2 medial elbow exposure techniques were then performed in the following manner.

FCU Splitting Approach

The ulnar nerve was identified as it ran behind the medial epicondyle. It was traced down to the natural split between the two heads of the FCU (Fig. 1). Using a combination of blunt and sharp dissection, an interval was developed between the ulnar and humeral heads of the FCU. The interval was extended distally to the first motor branch of the ulnar nerve, which was preserved. Articular branches of the ulnar nerve were sacrificed. The anterior portion of the FCU and flexor-pronator mass was then elevated off the coronoid and retracted anteriorly. One retractor was placed superior to the coronoid, 2 more retracting the split FCU at the base of the ulna, and another retractor at the superior origin of the ulna reflecting the top half of the split FCU and the rest of the pronator mass (Figs. 2A, B). Identical retractor placement was used on each specimen.

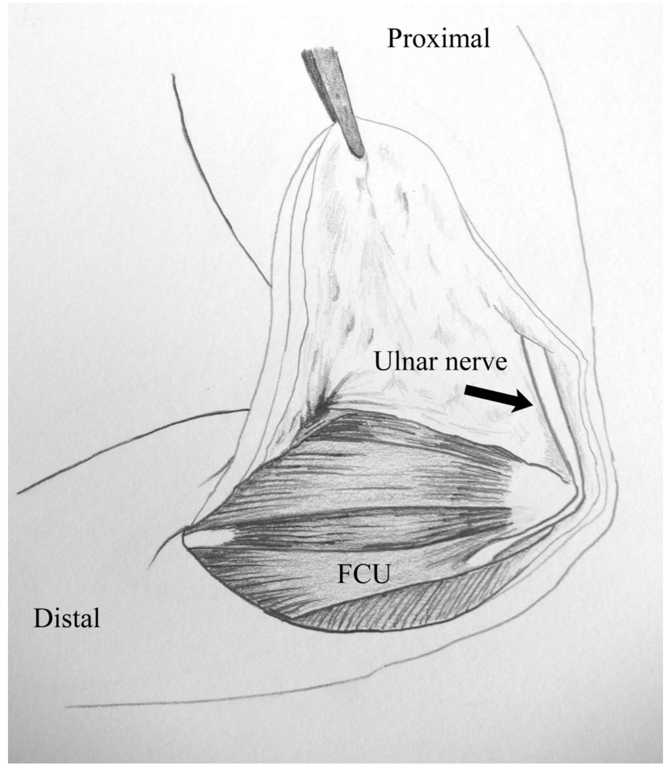

FIGURE 1. Diagram showing the initial approach for the FCU-Splitting approach. The ulnar nerve is retracted posteriorly.

Hotchkiss Over-the-Top Approach

The anterior margin of the flexor-pronator mass and the medial supracondylar ridge of the humerus was identified. The flexor-pronator muscle mass (between the ulnar nerve posteriorly and the anterior margin of the mass anteriorly) was split and the pronator teres was released from the medial epicondyle and reflected off the anterior elbow capsule and coronoid (Figs. 3A, B). The first retractor was placed medial to the coronoid to reflect the flexor carpi radialis and the

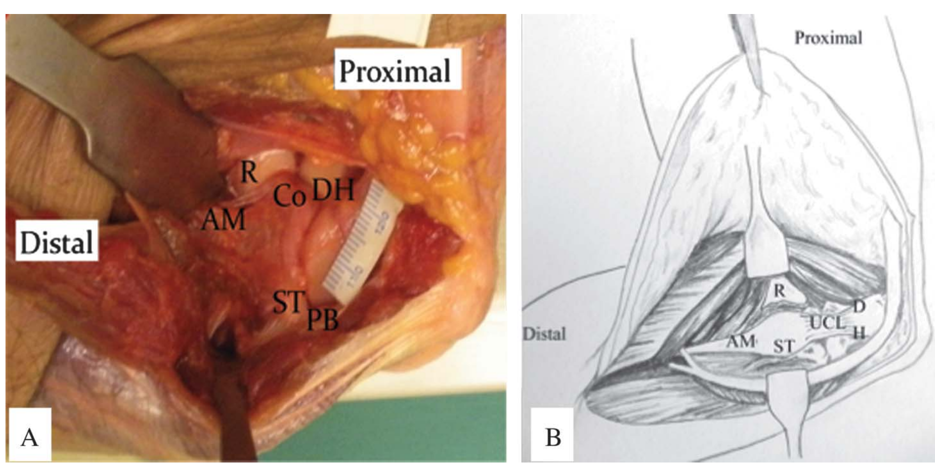

FIGURE 2. Photograph (A) and sketch (B) showing FCU-Splitting exposure of the anteromedial coronoid. The ulnar nerve is protected posteriorly. AM, anteromedial facet; Co, coronoid tip; DH, distal humerus; PB, posterior bundle of the MCL; R, radial head; ST, sublime tubercle. Editor's note: A color image accompanies the online version of this article.

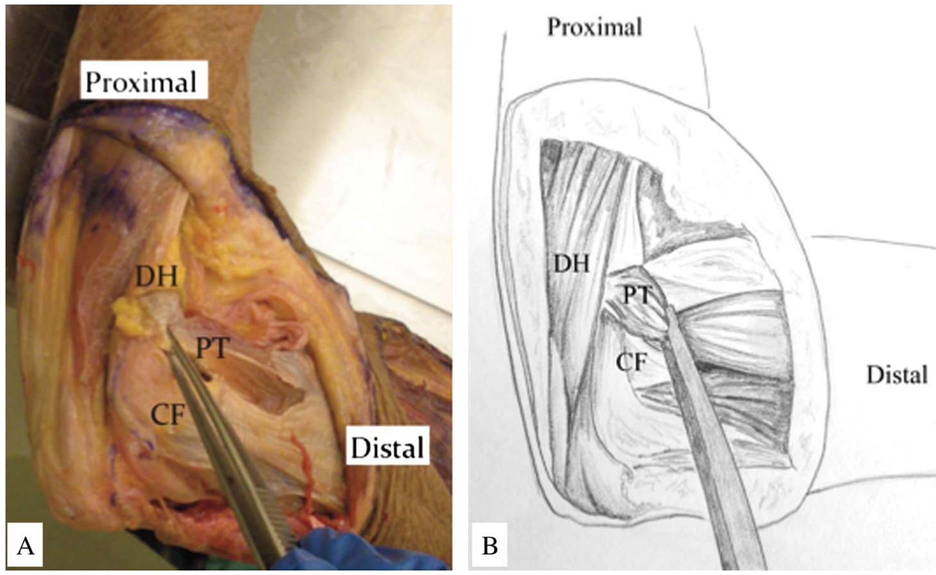

FIGURE 3. Photograph (A) and sketch (B) showing the takedown of pronator teres off of the medial epicondyle in the Hotchkiss Over-the-Top approach. The flexor-pronator muscle mass (between the ulnar nerve posteriorly and the anterior margin of the mass anteriorly) is split, and the pronator teres is released from the medial epicondyle and reflected off the anterior elbow capsule and coronoid. The ulnar nerve is protected posteriorly. CF, common flexor origin; DH, distal humerus; PT, pronator teres. Editor's note: A color image accompanies the online version of this article.

pronator mass. The second retractor was placed at the base of the coronoid anteriorly to the palamaris longus insertion (Figs. 4A, B). Identical retractor placement was used on each specimen.

Data Collection

Upon completion of each exposure, visible access to specific anatomic landmarks was assessed. These included the tip of the coronoid, anteromedial facet, sublime tubercle with its attachment of the anterior bundle of the MCL, posterior bundle of the MCL, and the radial head.

A calibrated digital photograph of the exposed coronoid process was then taken from a standard angle above the horizontal axis. This angle was determined by evaluating the osseous exposure provided by each exposure at different vantage points. The point that appeared to provide the most osseous exposure for each approach was determined to be the surgeon's best view. This was determined to be 60 degrees for the FCU-Splitting approach and 45 degrees for the Hotchkiss Over-the-Top approach. A protractor was used to ensure that the same angle was used for each photograph of each approach. These digital images were then analyzed using a computer program, ImageJ (National Institutes of Health, Bethesda, MD).[14] This computer program compares a known distance (ie, a metric ruler placed in each image) with the number of pixels in the digital photograph. Once calibrated, the exposed osseous area of the coronoid is outlined using the software program, which then calculates the surface area exposed.

A standardized measuring ruler was placed in the field of view to set the scale for the program. The scale was set using a standard distance of 1 cm. The osseous area being measured was then outlined, and the number of pixels contained within that area was calculated and converted to cm^2 using the previously set scale. This method of measuring osseous surface area has been used before[15–17] but has not been validated. Statistical analysis was performed using a Wilcoxon 2-sample test for nonparametric data, and significance was set at $P < 0.05$.

RESULTS

The described approaches were successfully performed in all specimens in sequential fashion. Available cadaveric demographic data is shown in Table 1. There were no statistically significant correlations between exposure and sequence of dissection, specimen age, gender, or laterality.

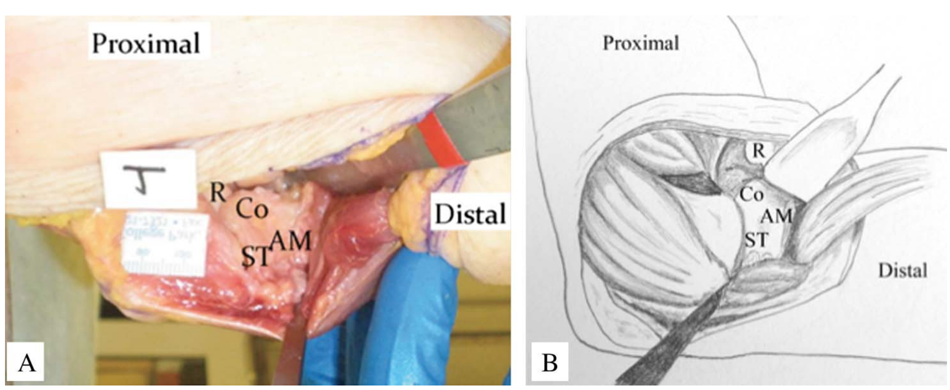

FIGURE 4. Photograph (A) and sketch (B) showing the exposure of the anteromedial coronoid using the Hotchkiss Over-the-Top approach. The ulnar nerve is protected posteriorly. AM, anteromedial facet; Co, coronoid tip; R, radial head; ST, sublime tubercle. Editor's note: A color image accompanies the online version of this article.

TABLE 1. Specimen Demographics

Average age (range), y	82 (66–93)
Gender	14 Males, 6 Females
Operative site	11 Right, 9 Left

The average surface area of coronoid exposed was 13.3 cm^2 (range 8.2–18.6, SD 2.8) using the FCU-Splitting approach compared with 4.4 cm^2 (range 2.6–11.2, SD 2.0) using the Hotchkiss Over-the-Top approach ($P < 0.0001$). Specimen measurements after each approach are listed in Table 2. It is noted that the majority of this extraosseous surface area seen using the FCU-Splitting approach included the proximal ulnar shaft.

All key anatomic landmarks were directly visualized with the FCU-Splitting approach in each specimen. Using the Hotchkiss approach, there was incomplete visualization of the sublime tubercle/anterior bundle of the MCL in 17 limbs (85%) and posterior bundle of the MCL in 20 limbs (100%) (Table 3).

DISCUSSION

Operative management of fractures involving the anteromedial facet of the coronoid has attracted interest over the last decade as we have gained a better understanding of this injury pattern.[18] Doornberg et al[19] only recently illustrated the relatively vulnerable protrusion of the coronoid's anteromedial facet, concluding that a separate medial exposure is most often required to stabilize this important structure in varus posteromedial rotatory injuries.

Both the Hotchkiss Over-the-Top and the FCU-Splitting approaches are described techniques for exposing the medial coronoid. Some suggest that the former approach is best for smaller fractures anterior to the sublime tubercle, whereas the latter is best for fractures involving the sublime tubercle and the MCL.[3,5,8,9] However, no quantitative or descriptive comparisons of these two approaches exist in the literature. The purpose of our study was to determine if there is any exposure difference between these two most frequently cited exposure techniques.[5,8–10] Based on the cadaveric specimens we examined, the FCU-Splitting approach offers increased osseous exposure of the coronoid process and more predictable access to the ligamentous structures on the medial side of the elbow, when compared with the Hotchkiss Over-the-Top approach.

TABLE 2. Specimen Measurements by Approach

Cadaver No.	FCU Splitting Approach, Square Area Exposed (cm^2)	Hotchkiss Approach, Square Area Exposed (cm^2)
1	14.393	4.026
2	16.422	11.279
3	15.985	3.803
4	12.721	7.339
5	9.825	4.91
6	8.219	5.474
7	12.334	3.385
8	13.825	5.352
9	18.087	2.571
10	14.411	3.227
11	14.024	2.896
12	18.66	3.841
13	12.377	2.998
14	13.59	4512
15	15.283	3.359
16	13.636	4.35
17	9.605	5.307
18	8.219	2.571
19	13.156	3.87
20	11.657	3.227

TABLE 3. Anatomic Landmarks Identified With Each Approach

Anatomic Landmarks	FCU-Splitting Approach (n/20)	Hotchkiss Approach (n/20)
Anteromedial facet	20 (100%)	20 (100%)
Coronoid tip	20 (100%)	20 (100%)
Sublime tubercle/anterior bundle MCL	20 (100%)	3 (15%)
Posterior bundle MCL	20 (100%)	0 (0%)
Radial head	20 (100%)	20 (100%)

Exploiting the interval between the two heads of the FCU has been described for use in creation of local muscle flaps.[20,21] A detailed anatomic study of the FCU has established the presence of two distinct neuromuscular compartments. This enables the muscle to be split into two separate compartments, each with its own vascular and nerve supply.[22] Thus, although the FCU-Split does not technically use an internervous plane as is used in the Hotchkiss approach, splitting the muscle into its two major heads (ulnar and humeral) comes with little risk of denervating the muscle.

Although several authors allude to use of the natural split of the FCU for coronoid fracture fixation,[3,5,8,9] the osseous exposure and anatomic landmarks have never been quantified in this context. In the sports medicine literature, Smith et al[23] defined a "safe zone" for a muscle-splitting approach about the medial elbow when repairing and reconstructing MCL injuries. Although their technique uses a more anterior interval along the posterior one-third of the common flexor mass, the authors discuss the advantages of a muscle-splitting technique over taking down the common flexor mass.[24]

Our study is not without limitations. First, as a cadaveric study, no definitive conclusions regarding clinical efficacy or safety can be made. There was no power analysis performed, either as we were limited by the number of cadaveric limbs available. This study relied on the limbs of older patients where the mean age was 82 years and was performed in an anatomy laboratory, which may not replicate the conditions in a true operating room setting. Second, although we used advanced digital imaging software, it relied on a 2-dimensional image to approximate the surface of a 3-dimensional structure. Additionally, the images were taken from a single perspective of the surgeon's view and did not take into account the surgeon's ability to use a mobile window of exposure through adjustment of his line of sight and retractor placement. These limitations may, therefore, underestimate the osseous exposure of one or both of these surgical approaches. Although the authors have

successfully used this software and methodology in previous publications[15,16] and many other scientific publications of similar methodology have used the ImageJ software,[17,25] it has not been validated. Finally, it is important to point out that this study was not designed to examine the overall efficacy of various exposure techniques for coronoid fracture fixation and did not seek to compare or confirm the potential advantages of each; instead, this study focused on quantifying the exposure difference obtained between two commonly cited techniques for anteromedial coronoid exposure.

In conclusion, the FCU-Splitting approach provides nearly three times more osseous exposure of the anteromedial coronoid and proximal ulna than the Hotchkiss Over-the-Top approach. The FCU-Splitting approach is able to provide adequate access to anteromedial coronoid fractures, including those anterior to the sublime tubercle, as achieved with the Hotchkiss approach. Because the FCU-Splitting approach carries the additional advantages of using the natural split between the two FCU muscle heads, maintaining the native origin of the flexor-pronator mass, and avoidance of the anterior neurovascular structures, we believe this technique can be considered for most anteromedial coronoid fractures that require medial elbow exposure. Future clinical studies are needed to confirm these results and determine the true efficacy of using the FCU-Splitting approach over the Hotchkiss approach for the management of anteromedial coronoid fractures.

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